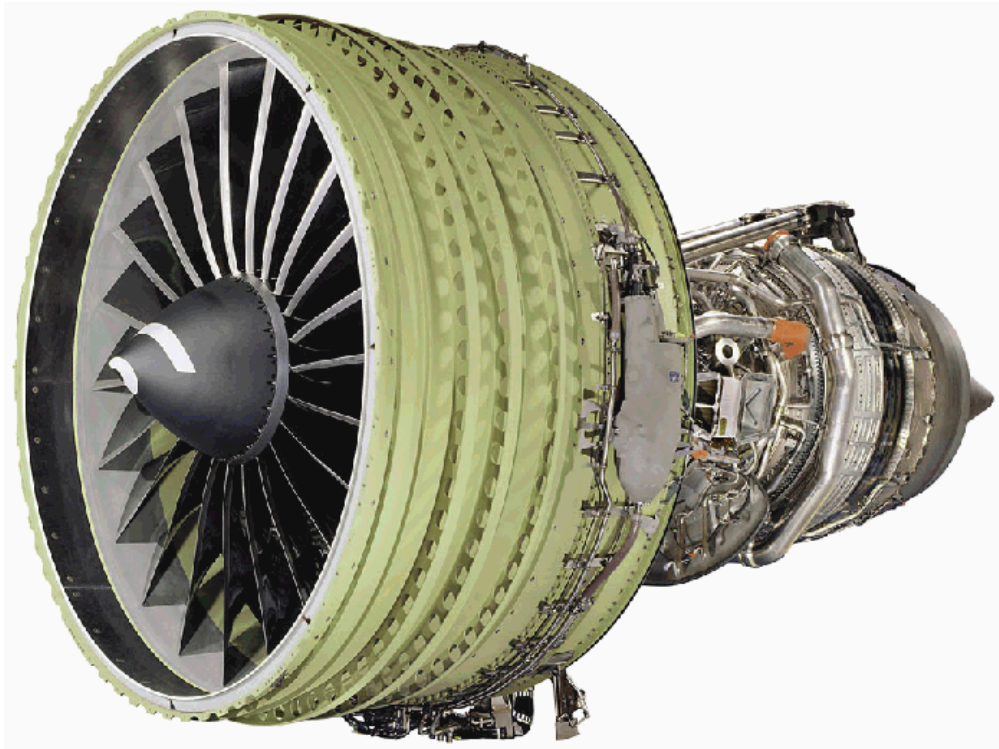
GE90 Fan Blade Service Experience and Repair



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FAA/EASA/Industry Composite Damage Tolerance and Maintenance Workshop

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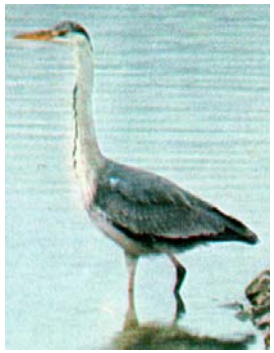
GE90 Composite Fan Blade

- GE90 fan blade is an all composite (carbon / toughened epoxy) design
- Extensive material design allowables program conducted
- Blade geometry driven primarily by aerodynamics (performance), aeromechanics (stability), impact (bird strike), low cycle fatigue (CF loads) and high cycle fatigue (vibratory response)
- Certification test requirements included …
  - > Operability – surge and stall; blade vibration
  - > Induction system icing
  - > Bird ingestion – 2.5 lb., 5.5 lb. and 8 lb. birds
  - > Foreign object ingestion – hail, water, ice slab
  - > Blade containment
  - > 2x overload (141% speed)
  - > Lightning strike
- Many of the engineering and certification tests included environmental exposure and effects of defects (mfg. defects and simulated handling damage)

Fan Blade Service Experience(1)

"Single" Bird Ingestion Event
October 4, 1998



Event Summary:
- Thrust level ... takeoff
- Aircraft speed ... V1 (~150 kts)
- Bird species ... Gray Heron
  - Weight ... ~3 lbs+
- Engine condition ... serviceable

Fan Blade Comparison

GE90-115B **GEnx**

GEnx … 3rd generation

"Multiple" Bird Ingestion Event
September 9, 2002

Event Summary:
- Aircraft ... on approach
- Airspeed ... ~200 knots
- Ingestion ... both engines
- Bird species ... Canadian Goose
  - Weight ... ~8 lbs
- Engine condition ... serviceable

Service Experience … approximately **eleven** years

Operational Experience … over **8.9 million** engine flight hours

> Only Three Fan Blades … retired from GE90 fleet 1st **6.0 million** engine flight hours

Reported Bird Ingestion Events … **120** Base GE90 and **15** GE90-115B

> Including … a Gray Heron and multiple Canadian Geese

GE90 Composite Fan Blade … has significant positive service experience to date

(1) As of 12/31/06

Fan Blade Field Sampling Program

- ***Return "partial sets" of fan blades ... for inspection***
  - Objective ... assess condition as blade ages
  - Partial set = seven fan blades (-94B)
  - Three airlines participating for each model
  - Recommended age … at planned inspections:
    - 1000 to 1500 CSN
    - 2000 to 2500 CSN
    - 3750 to 4250 CSN
    - 6750 to 7250 CSN
    - 9750 to 10,250 CSN
- ***Inspection includes:***
  - Full non-destructive test
  - Dovetail wear and MLE guard erosion
  - Moisture content assessment
- ***Data shared with FAA periodically***

(Suction Side)

Serial No. ... CFNA 0804
CSN 5581
TSN 11485

FAA considers this program a benchmark in industry practice for safety management with new technologies

Fan Blade Erosion and Wear Assessment

- ***Erosion Assessment***
  - Leading edge guard ... small amount observed directly on nose - quantification showed small erosion depth
  - Tip region ... no erosion
  - Trailing edge region ... no erosion
  - Airfoil ... pressure side
    * Polyurethane surface ... Some erosion observed
    * Surface adjacent to leading edge guard ... some paint peeling

- ***Wear Assessment***
  - Dovetail pressure faces ... no significant wear
  - Platform wear strips ... Some local wear observed

Serial No. ... CFNA 0804
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Additional Fan Blade Inspections and Tests

- GE is conducting destructive tests on a field returned blade or blades on an opportunistic basis

- Testing includes:
  - > Residual HCF capability
  - > Residual LCF capability
  - > Residual static strength capability
  - > Inspection for undetectable damage via cutups and photo-micrographs
  - > Evaluation of moisture absorption at specific blade locations
  - > Natural frequency and mode shape characteristics

All characteristics have been within expectations

Fan Blade ... Repair Summary

- ***Source Substantiated Repairs***
  1. Leading Edge Guard … replacement
  2. Tip Cap … replacement
  3. Trailing Edge Guard … replacement
  4. Platform Wear Strip … replacement
  5. Dovetail Wear Strip … replacement
  6. Polyurethane Erosion Coating … replacement
  7. AF32 Erosion Coating ... Replacement

- ***All these repairs are source substantiated … some required significant testing to validate capability***

- ***Most use production tooling***

- ***Repair Source***
  - CFAN … located in San Marcos, Texas
  - All “Source Substantiated” Repairs … in production

(San Marcos, Texas)

Fan Blade ... Additional Repairs

- ***Approved Repairs***

1. Metal Adhesive Flash ... repair
2. Platform Wear Strip ... frayed or disbond repair
3. Dovetail Wear Strip ... frayed or disbond repair
4. Polyurethane Erosion Coating ... local replacement
5. AF32 Erosion Coating ... local replacement
6. Composite Shank ... local blend repair
7. Paint ... local “touch up”
8. Composite Airfoil ... trailing edge delamination repair
9. Leading edge guard … blend repair
10. Composite airfoil tip … sealing repair
11. Composite airfoil … impact repair

- ***More repairs are in development***

- ***Repair Source***
  - CFAN … located in San Marcos, Texas
  - All “Approved” Repairs … in production

(San Marcos, Texas)

imagination at work

Summary

- GE90 fan blade exhibiting excellent performance in the field

- Service evaluation program in place

- Fan blade repairs in place for most types of damage experienced